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Published
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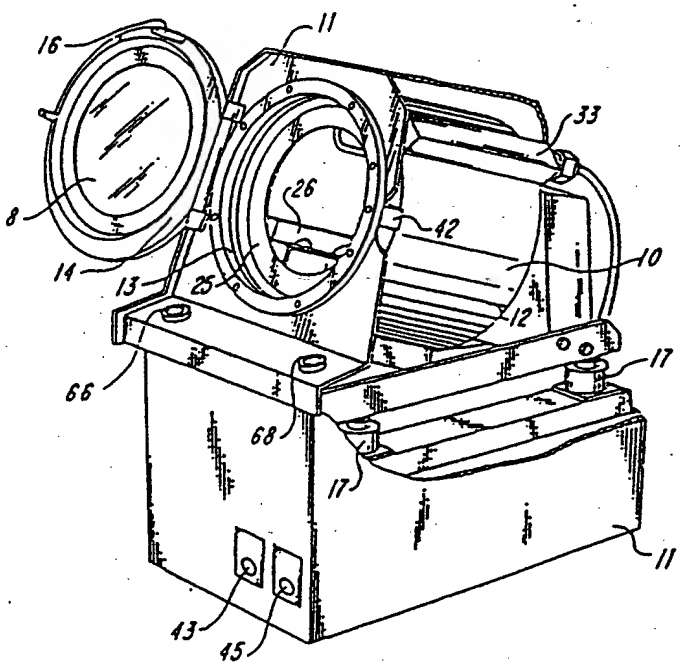
With amended claims and statement

(54) Title: CENTRIFUGAL WAFER PROCESSOR

(57) Abstract

An automatic production apparatus (10) for processing a plurality of semiconductor wafers, which includes a rotor (15) rotatable about a substantially, but not true, horizontal axis, wherein the rotor includes a removable carrier (38) capable of holding a plurality of closely loaded semi-conductor wafers and a support for retaining semiconductor wafers in the carrier when the carrier is inverted. It also includes a plurality of spray nozzles (33, 35) for providing processing fluids and drying gases, and a recessed drain (23) for removing the expended fluids.



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CENTRIFUGAL WAFER PROCESSOR

BACKGROUND OF THE INVENTION

This invention relates to an apparatus for processing semiconductor wafers, and more particularly, to machine operated functions for improving the processing yield of semiconductor wafers.

In the production of integrated circuits, the semiconductor wafers, or substrates from which the chips are cut, are processed through multiple steps. The basic substrate materials for wafers are, for example, silicon, glass ceramic materials or other similar materials of very thin wafer-like configuration. This basic substrate is subjected to coating, etching, and cleaning processes. It is extremely important that each processing step be performed with the greatest possible yield, thus allowing a decrease in production costs.

Semiconductor wafers in the past have been processed by spinning them about a vertical axis where the wafers are stacked vertically, as described in U.S. Patent 3,760,822, with various holding mechanisms such as vacuum chucks. However, this allows the wafer to be effectively processed on only one side at a time since the underside is processed at a much faster rate than the topside.

Other processing devices, such as described in U.S. Patent 3,970,471, process each wafer individually about a horizontal axis. However, such a device can only process a single wafer at each station, and is therefore time consuming and expensive.

None of the known prior art permits the processing of a plurality of wafers at the same time, with each side of the wafer being processed at effectively the same rate.

SUMMARY OF THE INVENTION

In accordance with the present invention, apparatus is disclosed in which semiconductor wafers, glass photomask plates, or the like, are processed by inserting them into a special carrier, and then placing the carrier in a rotor at an orientation which rotates the wafers substantially about their horizontal axes. For the purposes of this case, horizontal is defined as that imaginary line running between 270° and 90° of a compass. Various fluids can then be applied to the wafers, uniformly, through the spray nozzels while the wafers are being rotated. Chemical processing such as etching can also be performed on both sides at the same rate due to the substantially horizontal axis of rotation. In preferred embodiments spray nozzles are located above and to the side of the carrier, thus permitting the spraying to be done at relatively low pressures. This is especially desirable when hazardous materials are being used in the spraying steps. Furthermore, having the spray nozzles to the side of the carrier is beneficial as it eliminates the possibility of a nozzle leaking or dripping on a wafer during the drying process and potentially ruining a good wafer. Loading of the carrier of the present invention into the rotor of the present invention is simplified because of the substantially horizontal loading. As an additional advantage, there are built-in shock absorbers in the system so that any vibration from the spinning action is not transferred to the work station.

BRIEF DESCRIPTION OF THE DRAWING

The aforementioned and other features, characteristics and advantages, and the present invention in general will be better understood from the following description taken in conjunction with the accompanying drawings, in which:

FIG. 1 is a perspective representation, partially broken away, of the apparatus of the present invention.

FIG. 2 is an enlarged perspective representation of the rotor-carrier portion of the apparatus.

FIG. 3 is a cross-sectional view of the apparatus of FIG. 1 which also schematically represents the washing apparatus;

FIG. 4 is a cross-sectional view taken along line 4 - 4 of FIG. 3.

DESCRIPTION OF THE INVENTION

Referring now to the drawings, an apparatus 10 for processing wafer or semiconductor components is illustrated in FIG. 1. The apparatus of the present invention includes some similar components and functional relationships to existing front loading washing machines, which similarities will be apparent from the discussion which follows.

Apparatus 10, as shown in FIG. 1, has a somewhat rectangular outer configuration and a front opening. This style of apparatus is sometimes referred to as a front-loading machine indicative of the loading position. Apparatus 10 includes frame and cabinet assembly 11 which houses stationary tub 12 having front opening 13. Hinged door 14 on frame 11 is arranged to seal with respect to tub opening 13 so that the tub and door provide an enclosed fluid processing chamber. Door 14 also includes vent 16, capable of being opened and closed, and fluid tight viewing window 8.

Tub 12 is preferably constructed of corrosion and solvent resistant material, such as stainless steel. Tub 12 is a cylindrically shaped container with recessed drain 23 along its bottom, as shown in FIGS. 3 and 4, for the easy removal of processing fluids during processing cycles.

Concentrically positioned within tub 12 is rotor 15, including fixed support members 26 and movable support rod 28. Rotor 15 is mounted within tub 12 for rotation by the connection of central axle 18 (FIG. 3) which is sealingly received and supported by bearing mount 19. The center axis of bearing mount 19 defines by extension the axis of rotation for rotor 15. A pulley and belt connection 20 external to tub 12 couples axle 18 through bearing mount 19 to motor 21. Motor 21 thus provides driving means for rotating rotor 15 within tub 12.

Tub 12 is esentially stationary, connected to frame 11, and is supported to diminish vibrations by shock absorbers 17. Connected into tub 12 are a plurality of spray members, for example, 33 and 35 which are above and to the side of the wafers being treated in carrier 38 as shown in FIG. 4.

Carrier 38, having a plurality of disc location grooves, is capable of being slid into and out of rotor 15, mating snugly with supports 26 when in place in the rotor.

In the practice of the present invention, semiconductor wafers are placed in carrier 38, which is in turn placed within support members 26 of rotor 15 as shown in FIG. 2. Initially, support rod 28, as shown in FIG. 2, retains the semiconductor wafers in carrier 38 when rotor 15 is revolving at relatively low speeds. As the speed of rotation of rotor 15 increases, the semiconductor wafers are held in place by centrifugal force. The semiconductor wafers are processed by the application of various fluids through spray members 33 and 35. Rotor 15 rotates around a substantially horizontal axis, however in preferred embodiments the angle of the axis of rotation of rotor 15 is slightly greater or lesser than horizontal. This angle assists in preventing closely

loaded semiconductor wafers from contacting each other during processing. If the semiconductor wafers were to contact each other during processing, fluid blockage could occur or surface tension could exist which would prevent processing of the semiconductor wafers in the area of contact or wetting with each other, thus resulting in lower yields. By providing rotor 15 with an axis angle greater or less than exactly horizontal, surface tension problems are avoided. In the preferred embodiment the angle of the axis of rotor 15 is about 10° above horizontal as shown in FIG. 3. This angle also adds to the ease of loading of the semiconductor wafers, since, as a result of the angle, carrier 38 easily gravity feeds into support members 26 without the requirement of a retaining device to prevent carrier 38 from falling out of apparatus 10.

A high rate of rotation of the semiconductor wafers by rotor 15 allows the pressure of the processing fluids applied by spray members 33 and 35 to be low, thereby reducing costs by the elimination of high pressure equipment. Spray members 33 and 35 in the preferred embodiment may separately carry, for example, processing fluids and nitrogen to permit safe optimum performance.

During spraying and drying operations, the semiconductor wafers may be observed through window 8 of door 14. During the processing steps, except those in which nitrogen is used, air may be brought in to the tub through vent 16 to allow efficient evacuation of processing fluids through drain 23.

In preferred embodiments, apparatus 10 will not operate until door 14 is closed and positively locked with locking switch 42. The speeds at which the semiconductor wafers are rotated are controlled by switches 43 and 45. For example, Rinse Timer RPM control 43 controls the speeds during the liquid processing steps and Dry Timer/RPM control 45 controls the speeds during the drying steps.

In operation, semiconductor wafers are placed in carrier 38 which is inserted into support members 26 of rotor 15. Upon closing door 14 and locking switch 42, apparatus 10 may be started by turning power switch 66 on and activating start/stop switch 68, shown in FIG. 1. Rinse Time/RPM unit 43 provides the proper time and speed for liquid processing steps.

During rinse cycles, various liquids are dispensed through spray member 33 for the cleaning and processing of the semiconductor wafers. In preferred embodiments, the rinse cycle is determined to be complete by conitoring the rinse water at drain 23 with D.I. resistivity meter 40. As already noted, drainage is aided by air flow into tub 12 through vent 16. When the resistivity of the rinse water is determined to be approximately that of the water or other rinse fluid dispersed from spray member 33, then the Dry Timer/RMP unit 45 is activiated. Referring to FIG. 4, during the drying cycle, nitrogen is heated by heat element 37 in spray member 35 and is applied to the revolving semiconductor wafers at a sufficient pressure that outside air is not allowed to be drawn in through vent 16.

Because the semiconductor wafers and carrier 38 are not always the same weight, carrier 38 is constructed to rotate slightly off center, thus allowing the semiconductor wafers to be held in the carrier 38 by centrifugal force at high rotational speeds. Shock absorbers 17 are useful in eliminating vibrational energies from being transferred to the surface on which apparatus 10 is resting. Rotor 15 rotates about a substantially, but not true, horizontal axis.

The angle of the axis of rotation of axle 18, rotor 15, carrier 38 and the axes of rotation of wafers carried by carrier 38, may be in the range of from about 91° to about 135° or about 225° to about 269°, and angles reciprocal thereto. The preferred angle is in the range of about 95°

to about 105° or about 255° to about 265° with the angle shown being approximately 10° above the horizontal, or about 100°. As used herein, horizontal is defined as an imaginary line running from 90° to 270° of a compass.

While particular embodiments of the present invention have been shown and described, it is apparent that changes and modifications may be made without departing from the spirit and scope of this invention in its broader aspects. What is claimed is:

CLAIMS

1. An apparatus for processing semiconductor type wafers comprising:

a frame;

a tub, said tub including side-walls, an end-wall, and an opening opposed to said end-wall, said tub supported by said frame;

an axle having a first end and a second end, said axle sealingly mounted for rotation through said end-wall of said tub, at a substantially, but not true, horizontal axis, said first end of said axle being within said tub and said second end of said axle being outside of said tub;

rotor means, said rotor means being within said tub and connected to said first end of said axle, for rotation within said tub with said axle substantially at the angle of said axle,

means for carrying a plurality of closely loaded wafers, said carrier means designed to be supported by and rotated within said tub by said rotor means at an orientation such that wafers carried by said carrier will have their axes of rotation substantially at the angle of said axle;

fluid insertion means, said fluid insertion means connected through the sidewall of said tub to allow fluids to be inserted into said tub for processing wafers carried by said carrier means;

tub drain means for the removal of fluid, said drain means located in the side-wall portion at the bottom of said tub;

tub closure means mounted to close and open said tub at said open end of said tub opposed to said end-wall; and drive means, said drive means joined to said second end of said axle for rotation of said axle, and thereby also for rotation of said rotor means, said carrier means and wafers carried by said carrier means.

2. The apparatus of claim 1 in which a fluid seal is carried by said tub end-wall, said axle is mounted through said fluid

seal and connected at its second end to bearing means, said fluid seal and bearing means being designed to prevent the escape of processing fluids from said tub, and in which pulley means are located to connect said drive means to said bearing means and axle.

3. The apparatus of claim 1 in which movable wafer support means are mounted within said tub, said support means located for movement into a position to support wafers carried by said carrier means, and also movable away from said wafer support position, whereby, when carrier means carrying wafers are placed into said tub for support by said rotor means, said wafer support means are located for support of wafers carried by said carrier means, and then, when processing is completed, said wafer support means is moved away from its wafer support position.

4. The apparatus of claim 1 in which said tub closure means includes a positive fluid seal whereby when said closure means is closed, substantially all fluids within said tub are retained within said tub.

5. The apparatus of claim 4 in which said closure means includes vent means, said vent means designed to allow external air to enter said tub, thereby aiding in the removal of fluid from said tub at said drain means.

6. The apparatus of claim 1 in which said tub means is made from corrosion and solvent resistant material selected from the group consisting of stainless steel, polypropylene, and polyethylene.

7. The apparatus of claim 1 in which said fluid insertion means includes heating means to heat processing fluids or gases prior to their insertion into said tub.

8. The apparatus of claim 1 in which said drain means includes resistivity monitoring means to determine the resistivity of fluids being drained from said tub, thereby

providing information as to when the tub and wafers have been thoroughly rinsed of processing fluids.

9. The apparatus of claim 1 in which the angle of said axle is selected from the ranges of about 91° to about 135° and about 225° to about 269°, and reciprocals thereof, wherein the angle from 90° to 270° of a compass is defined as horizontal.

10. The apparatus of claim 4 in which the angle of said axle is selected from the ranges of about 95° to about 105° and about 255° to about 265° and reciprocals thereof.

11. The apparatus of claim 9 in which the angle of said axle is selected from about 100° and about 260°, and reciprocals thereof.

AMENDED CLAIMS
(received by the International Bureau on 29 July 1981 (29.07.81))

1. An apparatus for processing semiconductor type wafers comprising:
a frame;
a tub, said tub including side-walls, an end-wall, and an opening opposed to said end-wall, said tub supported by said frame;
an axle having a first end and a second end, said axle sealingly mounted for rotation through said end-wall of said tub, at a substantially, but not true, horizontal axis, said first end of said axle being within said tub and said second end of said axle being outside of said tub;
rotor means, said rotor means being within said tub and connected to said first end of said axle, for rotation within said tub with said axle substantially at the angle of said axle;
means for carrying a plurality of closely loaded wafers, said carrier means designed to be supported by and rotated within said tub by said rotor means at an orientation such that wafers carried by said carrier means will have their axis of rotation substantially at the angle of said axle;
fluid insertion means, said fluid insertion means connected through the sidewall of said tub to allow fluids to be inserted into said tub for processing wafers carried by said carrier means;
tub drain means for the removal of fluid, said drain means located in the side-wall portion at the bottom of said tub;
tub closure means mounted to close and open said tub at said open end of said tub opposed to said end-wall; and
drive means, said drive means joined to said second end of said axle for rotation of said axle, and thereby also for rotation of said rotor means, said carrier means and wafers carried by said carrier means.

2. The apparatus of claim 1 in which a fluid seal is carried by said tub end-wall, said axle is mounted through said fluid

seal and connected at its second end to bearing means, said fluid seal and bearing means being designed to prevent the escape of processing fluids from said tub, and in which pulley means are located to connect said drive means to said bearing means and axle.

3. The apparatus of claim 1 in which wafer support means are mounted within said tub, said support means located to retain wafers carried by said carrier means, whereby, when carrier means carrying wafers are placed into said tub for support by said rotor means, said wafer support means are located for support of wafers carried by said carrier means when said carrier means is rotated to an inverted position.

4. The apparatus of claim 1 in which said tub closure means includes a positive fluid seal whereby, when said closure means is closed, substantially all fluids within said tub are retained within said tub.

5. The apparatus of claim 4 in which said closure means includes vent means, said vent means designed to allow external air to enter said tub, thereby aiding in the removal of fluid from said tub at said drain means.

6. The apparatus of claim 1 in which said tub means is made from corrosion and solvent resistant material selected from the group consisting of stainless steel, polypropylene, and polyethylene.

7. The apparatus of claim 1 in which said fluid insertion means includes heating means to heat processing fluids or gases prior to their insertion into said tub.

8. The apparatus of claim 1 in which said drain means includes resistivity monitoring means to determine the resistivity of fluids being drained from said tub, thereby

providing information as to when the tub and wafers have been thoroughly rinsed of processing fluids.

9. The apparatus of claim 1 in which the angle of said axle is selected from the ranges of about 91° to about 135° and about 225° to about 269°, and reciprocals thereof, wherein the angle from 90° to 270° of a compass is defined as horizontal.

10. The apparatus of claim 1 in which the angle of said axle is selected from the ranges of about 95° to about 105° and about 255° to about 265° and reciprocals thereof, wherein the angle from 90° to 270° of a compass is defined as horizontal.

11. The apparatus of claim 1 in which the angle of said axle is selected from either about 100° or about 260°, and reciprocals thereof, wherein the angle from 90° to 270° of a compass is defined as horizontal.

12. The apparatus of claim 1 in which said rotor means includes a plurality of support bars, each bar having a pair of opposed ends, said bars being substantially parallel to said axle, but spaced therefrom, said support bars providing support to and positioning of said wafer carrier means.

13. The apparatus of claim 12 in which said rotor means includes a pair of substantially circular support members, said circular support members being substantially parallel to, but spaced from one another at opposite ends of said rotor, said circular support members being substantially perpendicular to said axle as extended, each of the opposed ends of said support bars being connected to one of said circular support members.

STATEMENT UNDER ARTICLE 19

The amendment provides clarifying language for several claims of the invention. Claim 1 has been amended as to several minor matters of form. Claim 3 has been amended to indicate that the "support" need not be movable and to detail its function. Claims 10 and 11 have been amended to define "horizontal". Claims 12 and 13 have been added to indicate details of the rotor structure.

The amendment to the abstract is offered to show additional reference numerals "15" for the "rotor" and "28" for the "support". As the amendment to the abstract is optional, applicant requests its entry, but will accept its non-entry.

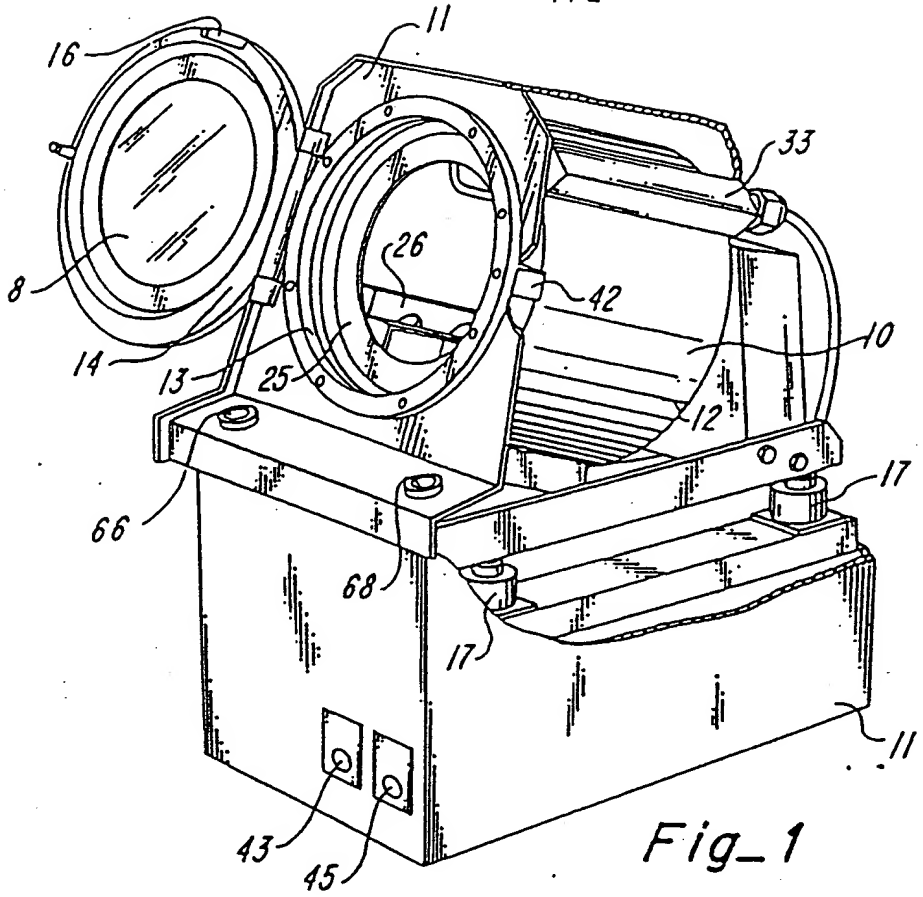

Fig_1

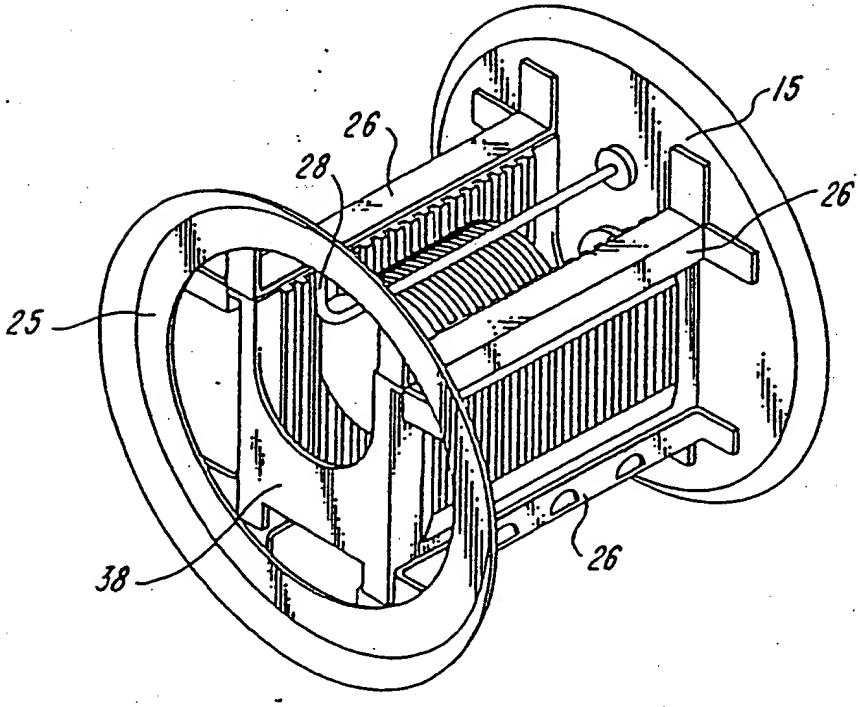

Fig_2

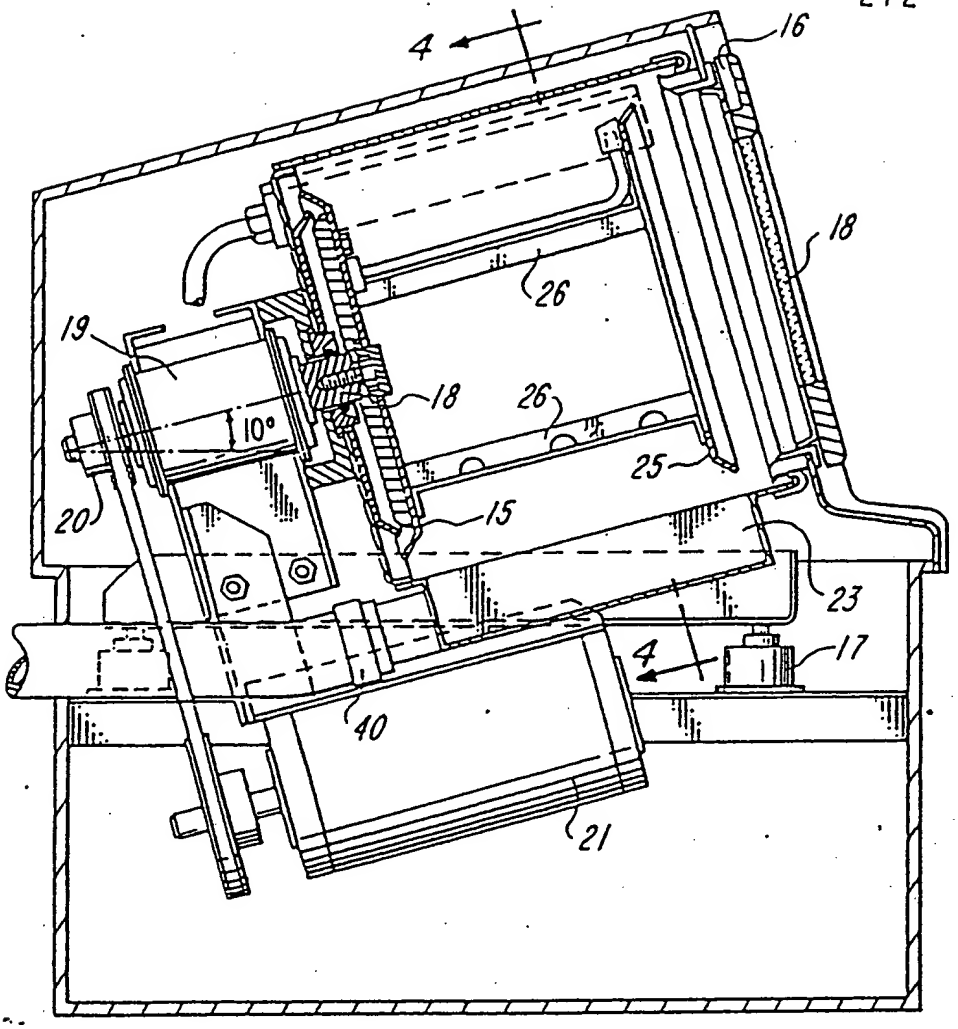
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Fig_3

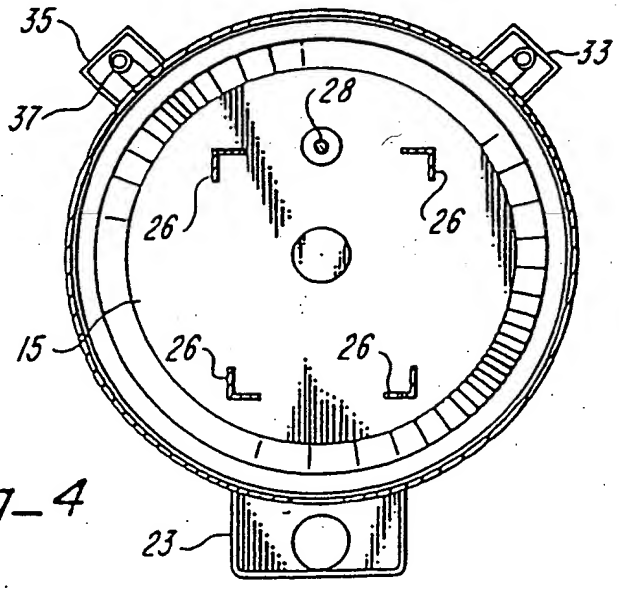
35
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Fig_4

INTERNATIONAL SEARCH REPORT

International Application No PCT/US81/00257

I. CLASSIFICATION OF SUBJECT MATTER (If several classification symbols apply, indicate all) [3]

According to International Patent Classification (IPC) or to both National Classification and IPC

INT. CL.³ B08B 3/02

U.S. CL. 134/57R,140,153,155,200; 156/345

II. FIELDS SEARCHED

Minimum Documentation Searched [4]

Classification System	Classification Symbols
U.S.	134/57R,140,149,153,155,158,159,165,200;156/345

Documentation Searched other than Minimum Documentation to the Extent that such Documents are included in the Fields Searched [5]

III. DOCUMENTS CONSIDERED TO BE RELEVANT [14]

Category *	Citation of Document, [16] with indication, where appropriate, of the relevant passages [17]	Relevant to Claim No. [18]
A	US, A 2,225,501, Published 17 December 1940, Lapham et al	1-11
A	US, A 2,684,585, Published 27 July 1954, Smith	1-11
A	US, A 3,383,255, Published 14 May 1968, Rossi et al	1-11
A	US, A 3,464,429, Published 2 September 1969, Ehrhardt	1-11
A	US, A 3,489,608, Published 13 January 1970, Jacobs et al	1-11
A	US, A 3,760,822, Published 25 September 1973, Evans	1-11
A	US, A 3,808,065, Published 30 April 1974, Robinson et al	1-11
A	US, A 3,964,957, Published 22 June 1976, Walsh	1-11
	Continued on second sheet	

* Special categories of cited documents: [15]

"A" document defining the general state of the art

"E" earlier document but published on or after the international filing date

"L" document cited for special reason other than those referred to in the other categories

"O" document refering to an oral disclosure, use, exhibition or other means

"P" document published prior to the international filing date but on or after the priority date claimed

"T" later document published on or after the international filing date or priority date and not in conflict with the application, but cited to understand the principle or theory underlying the invention

"X" document of particular relevance

IV. CERTIFICATION

Date of the Actual Completion of the International Search [2]	Date of Mailing of this International Search Report [2]
07 May 1981	04 JUN 1981
International Searching Authority [1]	Signature of Authorized Officer [20]
ISA/US	Robert L. Bleutge

FURTHER INFORMATION CONTINUED FROM THE SECOND SHEET

A	US, A, 3,970,471, Published 20 July 1976, Bankes et al	1-11
A	US, A, 4,077,416, Published 7 March 1978, Johnson, Jr., et al.	1-11
A	DE, A, 1,477,965, Published 4 June 1969, Graf et al	1-11
A	N, IBM Tech. Disclosure Bulletin, Vol. 10 No. 3, issued 3 August 1967, Mathisen, ETCH Control Probe, see pages 193 and 194	

V. ☐ OBSERVATIONS WHERE CERTAIN CLAIMS WERE FOUND UNSEARCHABLE [10]

This International search report has not been established in respect of certain claims under Article 17(2) (a) for the following reasons:

1. ☐ Claim numbers _____, because they relate to subject matter [12] not required to be searched by this Authority, namely:

2. ☐ Claim numbers _____, because they relate to parts of the International application that do not comply with the prescribed requirements to such an extent that no meaningful International search can be carried out [13], specifically:

VI. ☐ OBSERVATIONS WHERE UNITY OF INVENTION IS LACKING [11]

This International Searching Authority found multiple inventions in this international application as follows:

1. ☐ As all required additional search fees were timely paid by the applicant, this international search report covers all searchable claims of the international application.

2. ☐ As only some of the required additional search fees were timely paid by the applicant, this international search report covers only those claims of the international application for which fees were paid, specifically claims:

3. ☐ No required additional search fees were timely paid by the applicant. Consequently, this international search report is restricted to the invention first mentioned in the claims; it is covered by claim numbers:

Remark on Protest

☐ The additional search fees were accompanied by applicant's protest.

☐ No protest accompanied the payment of additional search fees.